Fire and Vegetation History of the Jemez Mountains

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Historic patterns of fire occurrence and vegetation change in the Jemez Mountains of northern New Mexico have been described in detail by using multiple lines of evidence. Data sources include old aerial and ground-based photographs, historic records, charcoal deposits from bogs, fire-scarred trees (Figure 1), tree-ring reconstructions of precipitation, and field sampling of vegetation and soils. The forests and woodlands that cloak the Southwestern uplands provide the most extensive and detailed regional-scale network of fire history data available in the world (Swetnam and Baisan 1996, Swetnam et al. 1999, Allen 2002).

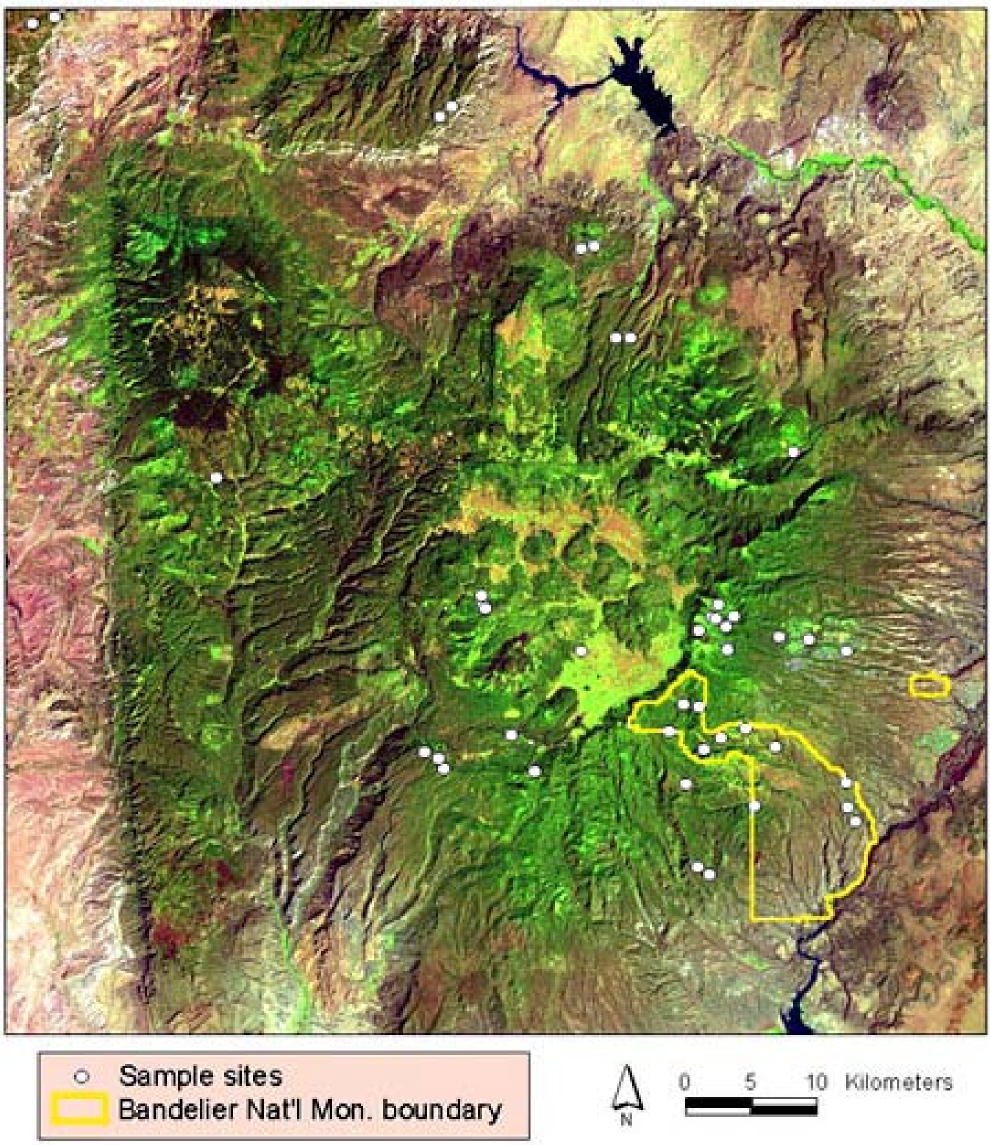

Figure 1 Map of fire scar sample site locations in the Jemez Mountains.

Modern climate/vegetation patterns basically developed in the Southwest ca. 11,000 to 8,000 years before present. Substantial fire activity apparently emerged in the Southwest during that time, as evidenced by the contemporaneous and rapid spread of fire-adapted ponderosa pine forests across the region (Anderson 1989), and by the abundant charcoal deposits found in lake and bog sediments (Brunner-Jass 1999, Weng and Jackson 1999). Charcoal sediments from Alamo Bog in the central Jemez Mountains indicate essentially continuous fire activity extending back almost 9000 years (Brunner-Jass 1999).

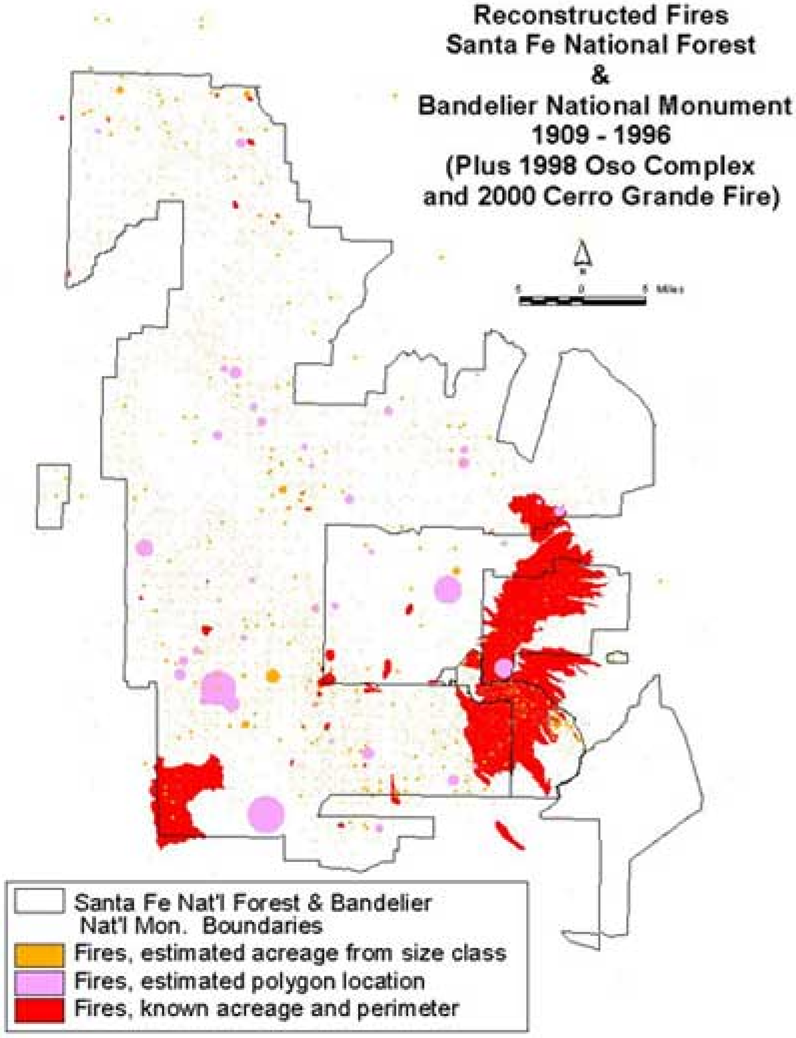

Figure 2. Point locations of historic wildfires in the Jemez Mountains, 1909-1996, compiled from the administrative records of land management agencies. Person-caused fires cluster near major roadways, campgrounds, habitations, and other human uses.

About 5200 historic fires have been mapped in the Jemez Mountains for the period 1909-1996 from administrative records of local land management agencies (Snyderman and Allen 1997, Figure 2). Lightning caused fully 75% of the recorded fires, with acreage burned peaking in the dry months of May and June before the onset of summer monsoonal rains. High levels of lightning activity naturally foster fire ignitions here. For example, 62 thunderstorm-days/year are observed at Los Alamos, generating large numbers of lightning strikes. An automated lightning detection system recorded 165,117 cloud-to-ground lightning strikes over a 775,554 ha area centered on the Jemez Mountains during the period 1985-1994 (Figure 3). The annual number of recorded lightning strikes varied between 9,410 and 23,317. Although lightning activity clearly peaks during the summer monsoon, strikes were recorded in every month. Particularly important for fire ignitions is the substantial lightning activity during the warm, dry, foresummer months of April through June, when many lightning strikes occur from sporadic storms or clouds generating only virga (rain which evaporates while falling and thus fails to reach the Earth's surface). These strikes are the most significant sources of fire ignition because lightning is much more likely to start a spreading fire if it strikes dry fuels. Because lightning ignitions are so frequent and ubiquitous in the Southwest, climate and fuel conditions are the main drivers of fire regime dynamics in this region.

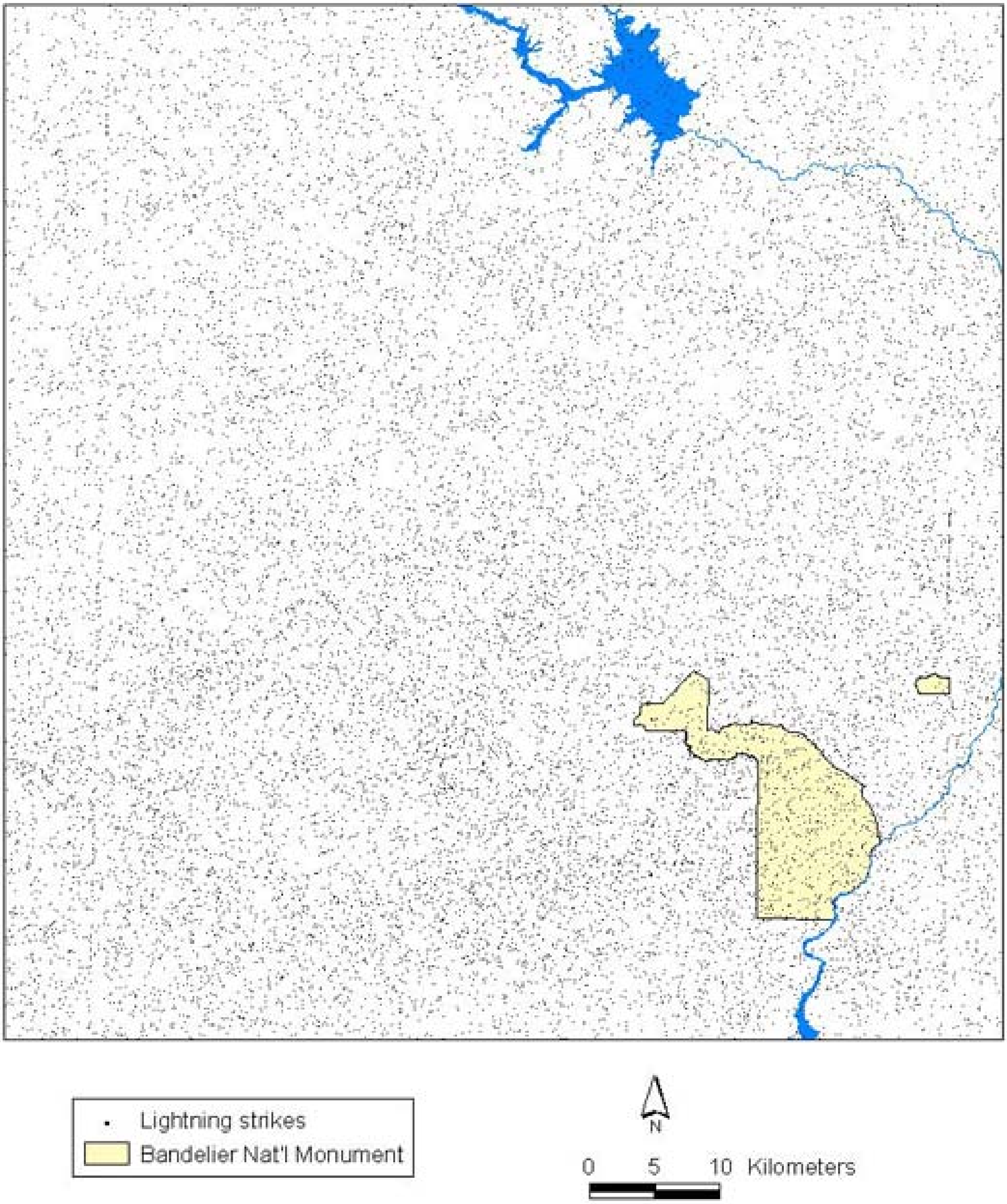

Figure 3. Map of 23,317 lightning strikes recorded across 775,554 ha in the Jemez Mountains area during 1986 by the national automated lightning detection system. The nominal resolution of the locational data is ~+/- 2 km.

Fire scars were sampled from over 600 trees, snags, and logs at 42 sites around the Jemez Mountains in northern New Mexico (Figure 1), resulting in over 4000 dendrochronologically-dated fire scars. Fire scar dates extend back to 1422 A.D. These data have been used to develop fire histories at multiple spatial scales, from individual trees to watersheds and finally the entire mountain range. Fire histories were reconstructed for vegetation types ranging from piñon-juniper woodlands up through ponderosa pine forests and mixed conifer forests into high-elevation spruce-fir forests (Touchan et al. 1996, Allen et al.1996). These fire histories show that frequent, low-intensity surface fires naturally characterized most Southwestern forests. These fires spread widely through grassy understory fuels, maintaining relatively open forest conditions (Figure 4).

Figure 4. Open ponderosa pine forest representing "typical" pre-1900 conditions, with grassy understory and surface fire activity.

Pre-1900 mean fire intervals ranged from 5 to 25 years across the Jemez Mountains (Figure 5). Significant spatial variation in past fire regimes is evident, depending upon such local factors as vegetation/fuel type, topography, and land use history. Fire frequencies and area burned have been greatest in mid-elevation ponderosa pine forests. Fire activity commonly occurred over extensive areas (Allen et al. 1998); e.g., watershed-wide fires occurred ~ every 16 years across the 15-km long Frijoles watershed in Bandelier prior to 1900 (Allen 1989). In some years fires apparently burned across most of the Jemez Mountains (Allen et al. 1998), and indeed even across the Southwest (Swetnam et al. 1999, see graphics at website**:** **http://biology.usgs.gov/luhna/chap9.html**).

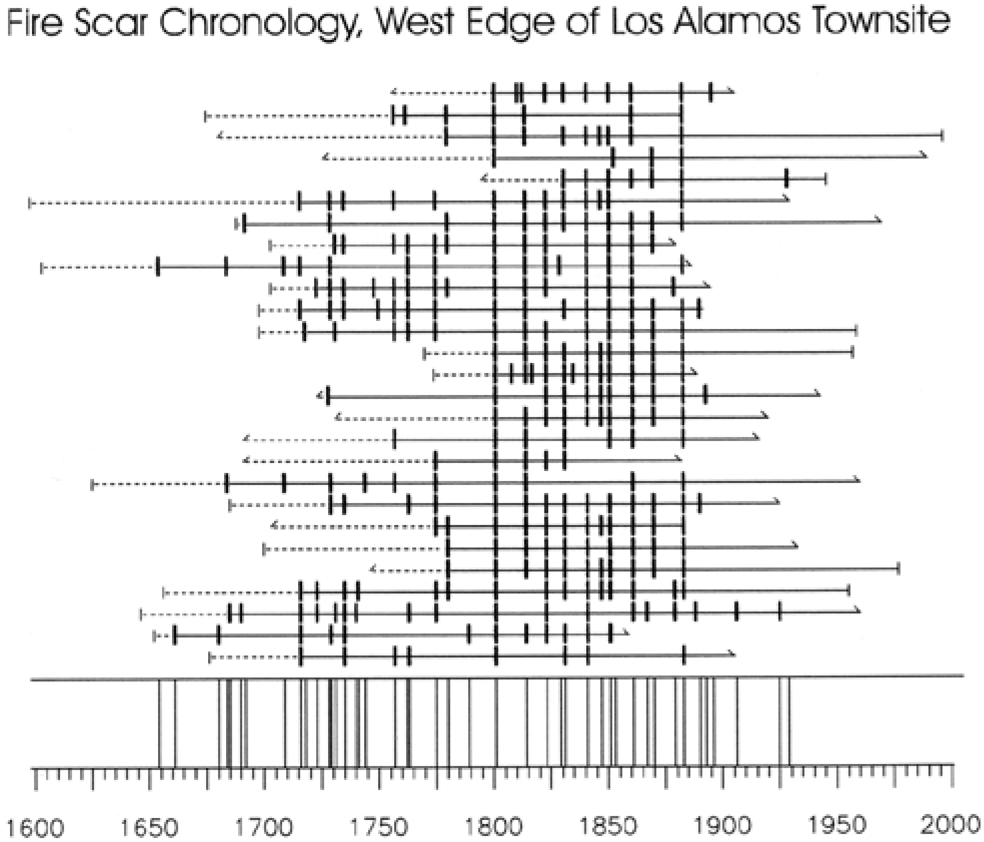

Figure 5. Fire scar chronology for Quemazon locality, western edge of Los Alamos townsite. Horizontal lines represent the life spans of individual trees, while fire scar events are shown by short vertical bars. Fire years are listed along the lower axis.

Climate variability acted to regionally synchronize prehistoric fire activity, as major fire years were clearly associated with drought conditions, while wet periods recorded little fire activity (Touchan et al. 1996, Swetnam and Baisan 1996, Swetnam and Betancourt 1998). The most extensive fire activity in ponderosa pine forests occurred in dry years that followed within one to three years of wet conditions; this pattern of major fire years suggests the importance of both fuel production and fuel moisture in these fire regimes, with antecedent wet conditions stimulating the buildup of continuous fuels and subsequent drought conditions enabling the fuels to burn widely (Swetnam and Baisan 1996). The common occurrence of persistent drought conditions in the Southwest likely allowed some fires to burn for months.

In most cases the seasonality of fire occurrence can be inferred by the relative position of a fire scar within the annual growth rings. The patterns of fire seasonality developed from prehistoric fire scars and modern fire records are generally indistinguishable, indicating that prehistoric fires occurred during the same seasons as modern lightning-ignited fires – predominantly in the spring and summer. Fall fires were rare.

Spatial patterns of consecutive-year fire events indicate the importance of herbaceous fuels in supporting fire spread in these pre-settlement forests. Railroads linked northern New Mexico to external markets ca. 1880, leading to a local boom in livestock numbers. Abrupt declines in fire frequency throughout the Jemez Mts. in the late 1800's (e.g., Figure 5), decades before active fire suppression, support the hypothesis of overgrazing-induced suppression of presettlement surface fire regimes as livestock (particularly sheep in mountain forests) literally ate the grassy fuels through which fires previously had spread. Fires would have repeatedly burned across widespread portions of the Southwest during the 20th Century if the numerous natural and human-caused fires had not been vigorously suppressed by fire-fighting actions after 1910 (Swetnam et al. 1999, Allen 2002).

This history of livestock grazing and fire suppression in the Jemez Mountains has driven such landscape-wide vegetation changes as: increased density of woody species and accelerated erosion rates in piñon-juniper woodlands; conversion of ponderosa pine forests into thickets (or crown-fire-created grasslands and shrublands); changes in species composition and structure in mixed conifer forests (Figure 6); and invasion of grasslands and meadows by trees and shrubs (Allen 1989).

Similar changes have occurred throughout the Southwest (Bogan et al. 1998; see graphics at website: **http://biology.usgs.gov/s+t/SNT/noframe/sw152.htm**). The increased densities of forests over the past century (often 10-fold increases) have markedly changed many ecosystem processes, including patterns of runoff and water yield from regional watersheds. For example, increased forest densities lead to decreases in total streamflow, peak flow, and base flow (Ffolliott et al. 1989), important concerns in the water-limited Southwest.

Figure 6. Altered ponderosa pine stand in need of restoration, showing changes in both stand structure and species composition. The dense midstory of mixed conifer trees provides ladder fuels that favor crown fire development.

Fire behavior has also greatly changed due to the landscape-wide buildups of woody fuels associated with a century of fire suppression. As a result the frequency and severity of wildfire activity (including lightning-ignited fires) has been escalating despite increasing human suppression efforts, as the mean number of lightning fires/year in the Southwest grew by over 50% from 1940-1975 (Barrows 1978); the mean annual acreage burned in the Southwest has increased continuously since ca. 1960 (Swetnam and Betancourt 1998); and unnatural stand-replacing conflagrations like the 1977 La Mesa Fire (Allen 1996), the 1996 Dome Fire (Figure 7), and 2000 Cerro Grande Fire are occurring more often in over-dense ponderosa pine forests (Covington and Moore 1994). Extensive (> 100 ha) stand-replacing fires rarely (if ever) occurred in pure, Southwestern ponderosa pine forests before the middle of the 20th century. Severe crown fires typically cause major watershed impacts, including accelerated flooding and erosion (Robichaud et al. 2002). Twentieth Century landscape scars created by stand-replacing fires in ponderosa pine and lower elevation mixed conifer are long-lasting legacies of human error in managing these ecosystems. Recovery of forest communities within such burned and eroded landscapes may not occur for centuries. Fire history data and evidence of extreme geomorphic responses following extensive crown fires provide strong justification for management programs aimed at preventing the future occurrence of these ecological and societal disasters (Covington et al. 1997, Allen et al. – in press).


Figure 7. Dome Fire, Day 2, April 26, 1996, near headwaters of Capulin Canyon.

Note that droughts can also cause extensive ecosystem changes by rapidly killing vegetation. For example, a severe, regional drought occurred during the 1950's in the Southwest. Associated tree mortality in the Jemez Mountains caused the ecotone between ponderosa pine forests and piñon-juniper woodlands to shift upslope by as much as 2 km in less than 5 years (Figure 8), while mixed piñon-juniper woodlands were converted to overstories of only juniper at many sites (Allen and Breshears 1998). The 1950's drought may have also reduced herbaceous ground cover in these ecotone areas, contributing to current high erosion-rates (Wilcox et al. 1996, Davenport et al. 1998). Projected global climate changes may render over-dense Southwestern forests increasingly susceptible to rapid dieback through drought-induced mortality, including associated insect outbreaks and crown fires (cf. Swetnam and Betancourt 1998). There is potential for large, rapid losses of global carbon stocks from climate-mediated disturbances like fire and drought mortality (Breshears and Allen 2002), since forests can dieback much more rapidly than they can grow.

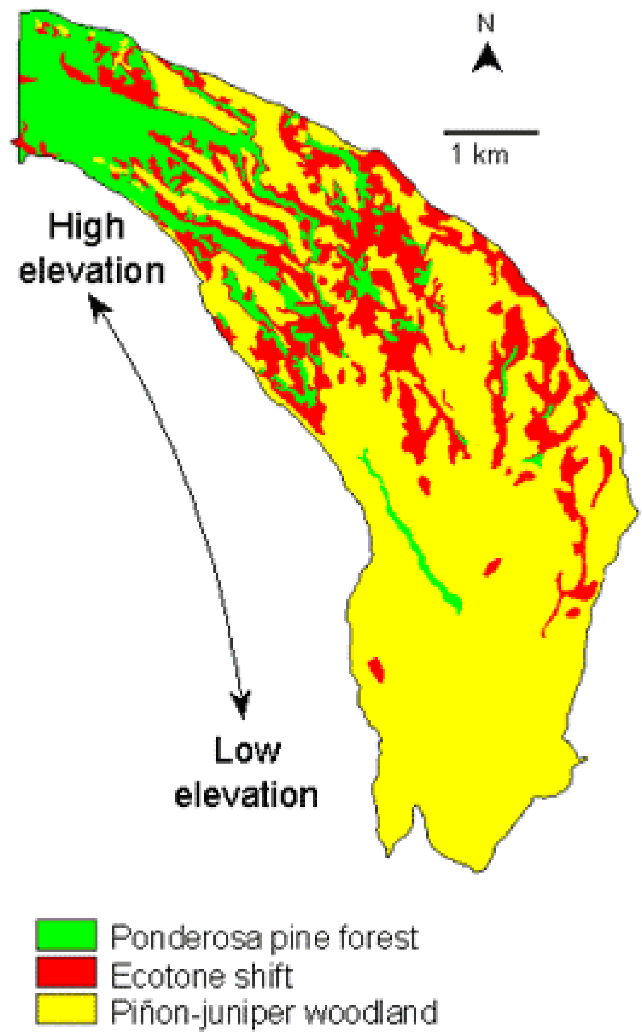

Figure 8. Changes in vegetation cover between 1954 and 1963 on Frijolito Mesa in Bandelier National Monument, showing persistent ponderosa pine forest, persistent piñon-juniper woodland, and the ecotone shift zone where forest changed to woodland.

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